Treating Calf and Pedal Vessel Disease: The Extremes of Intervention

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Abstract

Recent developments in catheter, balloon, and guidewire technology have increased the scope for endovascular treatments in the management of complex and challenging disease in the calf and foot. The antegrade femoral approach remains the starting point for most interventions, but there is a growing role for procedures performed from unconventional access such as the pedal arteries. This article reviews the indications for intervention, atypical access, and the choice of equipment for these extreme interventions.

Keywords

- ► below-the-knee
- ► below-the-ankle
- ► angiosome
- ► transpedal
- ► pedal–plantar loop
- ► interventional radiology

Objectives: Upon completion of this article, the reader will be able to describe the indications for catheter-directed therapy for occlusive disease of the calf and foot vessels as well as the technical issues specifically noted in this patient population.

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Chronic critical limb ischemia (CLI) is a major worldwide cause of morbidity and mortality.[1] Major and minor amputations are associated with significant increases in mortality, cost, and deterioration in quality of life, therefore every effort should be made to ensure limb salvage.[2] Patients with CLI typically require some form of revascularization to relieve rest pain and to expedite ulcer and wound healing.[2,3] Endovascular interventions are increasingly used to treat patients with severe infrapopliteal arterial disease with promising clinical results.[4–11]

Conventional percutaneous approaches and techniques remain the first choice for treating below-the-knee (BTK) and below-the-ankle (BTA) arterial occlusions.[12,13] However, these approaches will fail in up to 20% of patients and novel percutaneous approaches including pedal access, transcollateral recanalization and pedal–plantar loop techniques have been shown to be beneficial in increasing success rates.[4,14–17] Long total chronic occlusions, extensive mural calcifications and diffuse involvement of the foot arteries are particularly common in diabetic patients. These conditions pose considerable technical challenges for endovascular treatment regardless of approach[18] and even these alternative approaches may fail or be unfeasible, particularly when the BTA vessels are diseased.[15,18]

Targets in Critical Limb Ischemia Revascularization

Revascularization aims to reestablish sufficient inline blood flow to allow healing and avoid major amputation.[2] There are two strategies for revascularization: "complete" and "wound-related artery" (WRA) revascularization.

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"Complete" Revascularization

This is based on the principle that wound and ulcer healing is a blood flow–dependent phenomenon, hence the greater the flow the higher the chance of healing. This is especially important in patients with extensive tissue damage and infection. In these cases, the lesion is not confined to a single "angiosome" but spreads over contiguous foot spaces and angiosomes. Faglia et al reported outcomes in 993 diabetic patients with CLI treated with an angioplasty-first approach.[6] The majority of patients had calf vessel disease and the number of patent calf arteries increased after angioplasty with a corresponding increase in transcutaneous percutaneous oxygen saturation. Peregrin et al performed a retrospective analysis of 1,268 patients with CLI treated with infrapopliteal angioplasty[19]; technical success was 89% despite the majority of patients having Transatlantic Intersociety Consensus (TASC) D lesions. Limb salvage correlated with the number of patent calf arteries postangioplasty, ranging from 56% in the absence of in-line flow to the foot, to 73, 80, and 83% with 1, 2, or 3 patent calf vessels, respectively.

Hence, the principle underlying a "complete revascularization" strategy is to establish the best possible blood supply to the foot by restoring patency of as many of the calf arteries as achievable (►Fig. 1).

Angiosome "Wound-Related Artery" Revascularization

The concept of angiosome-oriented revascularization has gained popularity in recent years. A review of angiosomal anatomy is beyond the scope of this article but is described in detail by Manzi et al.[20] Successful revascularization of the artery directly feeding the ulcer area (the WRA) leads to a higher rate of limb salvage and wound healing.[21–25] Direct revascularization has a different efficacy depending on the outflow distribution network. Varela et al demonstrated that the restoration of blood flow to a wound through existing distal collateral vessels (pedal and peroneal branches) yielded similar healing and limb salvage to direct revascularization of the angiosomal artery.[26] However, when there is diffuse disease of the small distal vessels (diabetic and end-stage renal disease patients), healing requires direct blood flow to the WRA.[27]

The WRA concept has particular importance in cases of surgical wounds where "pulsatile flow" is required for healing. Forefoot amputations (ray, transmetatarsal, Lisfranc, and Chopart amputations) often interrupt the perforating metatarsal branches connecting the dorsum and the plantar vessels, separating the two systems. In these cases, flow from the WRA supplying the surgical flap must be optimized (►Fig. 2). When revascularization is performed before

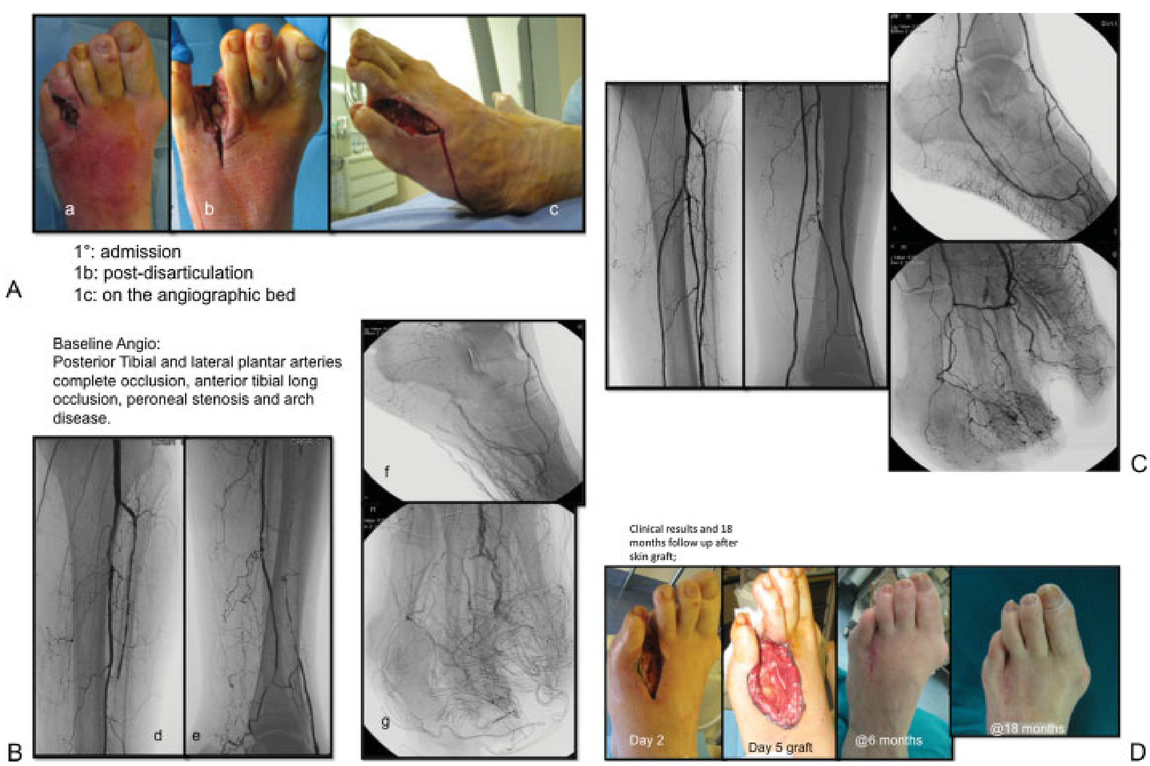

Figure 1 Patient undergoing distal revascularization to heal a postamputation of the 4th ray wound. (A) Clinical images demonstrating (a) preoperative appearance, (b) postdisarticulation appearance, and (c) preangiographic appearance of the left foot. (B) Angiographic images of the (d and e) left calf and (f and g) left foot demonstrating diffuse, multifocal occlusive disease. (C) Angiographic images following multilevel angioplasty with excellent angiographic response. Compare with B. (D) Clinical images at various stages postangioplasty with excellent clinical results.

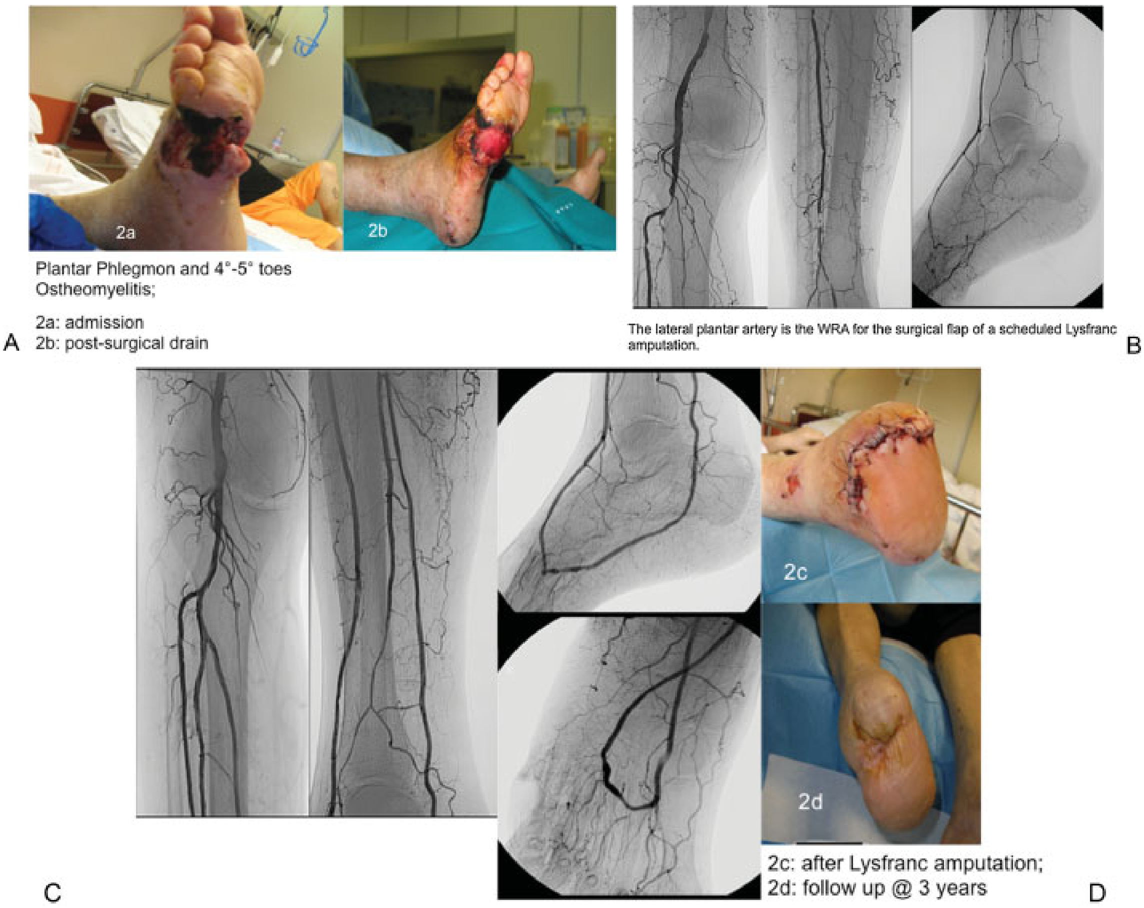

Figure 2 Patient presenting with severe osteomyelitis requiring a Lysfranc amputation. (A) Clinical preoperative images demonstrating severe infection involving the right foot (a) on admission and (b) following surgical drainage. (B) Preangioplasty angiogram demonstrating severe multifocal diffuse disease. The angiosome of interest is in the lateral plantar artery distribution. (C) Post angioplasty appearances. Angiographic and clinical results postangioplasty and surgery. (D) Clinical results (c) immediately post Lysfranc amputation and (d) after 3 years. AT, anterior tibial; PT, posterior tibial; TPT, tibioperoneal trunk; WRA, wound-related artery.

surgery, the likely postoperative circulation should be considered when deciding the WRA.

Strategy in Below-the-Ankle Vessels

There are several reports of angioplasty in BTA arteries.[3,10,17,28–31] These studies have proved the principle, safety, and feasibility of using standard subintimal or intraluminal recanalization techniques of the pedal and plantar arteries for limb salvage in cases of CLI.[31] Balloon angioplasty is the standard technique for treating pedal vessels; stenting is contraindicated due to the mechanical stress to which the stents will be subjected.[31]

The pedal–plantar loop technique and the retrograde accesses together with an antegrade ipsilateral CFA approach can increase the success rate of the revascularization and the clinical outcome, improving the wound-healing process.[3]

The Pedal–Plantar Loop Technique

The pedal–plantar loop technique is based on the wire and balloon tracking through the plantar arch, creating a loop from the dorsal to the plantar circulation of the foot (or vice versa).[30] The purpose of this technique is to restore direct arterial inflow between both main circulatory pathways of the foot, achieving a complete BTA revascularization even in the presence of only a single patent calf artery. It can also be successfully used when the antegrade approach has failed to obtain recanalization of an occluded calf vessel.

The technique can be performed either from the anterior tibial artery (ATA) or posterior tibial artery (PTA). In the former, a wire is maneuvered from the ATA into the dorsalis pedis artery (DPA) across the plantar arch into the lateral plantar artery (LPA), and then to the PTA. The posterior tibial approach is performed in reverse. This technique has been thoroughly tested and proven to be useful for recanalization of patients with CLI due to BTK and BTA atherosclerotic disease.[17] Using “roadmap” techniques and anteroposterior and lateral projections to demonstrate that anatomy is key to successfully navigating the pedal arch.[20] The plantar–pedal loop technique can achieve high technical success rates (85%) with good angiographic results and low rates of periprocedural complications.[17]

Before using the plantar–pedal loop technique, the operator must carefully analyze the vascular anatomy of the foot.[20] Clearly, the technique will not succeed in patients with an incomplete plantar arch in whom there is no direct communication between the dorsalis pedis and lateral plantar arch. Using this technique, direct blood flow through one tibial

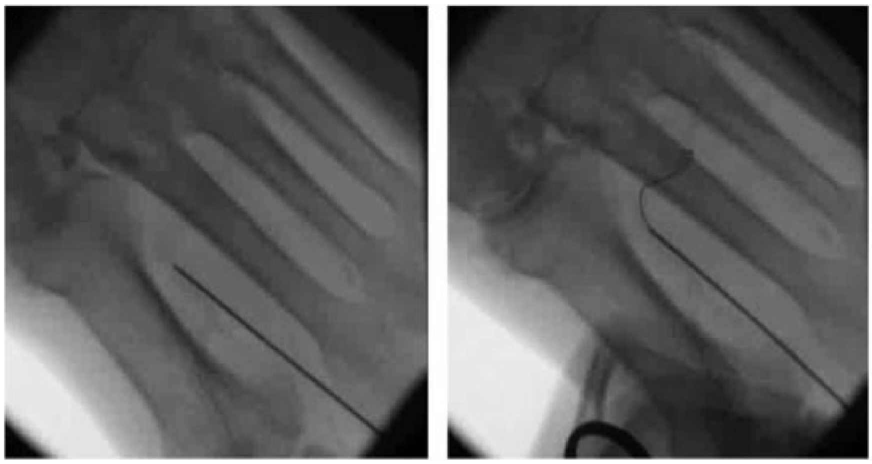

Figure 3 Fluoroscopic spot images demonstrating fluoroscopically guided retrograde transmetatarsal arterial puncture.

artery (ATA or PTA) with a good distal outflow into the foot vessels can be achieved in the majority of the patients. When pedal arch and the distal distribution system are not diseased, it is mandatory to avoid angioplasty, as this could lead to dissection or thrombosis without any possible benefit.

Retrograde Percutaneous Puncture

Transpedal access should be reserved for patients with Rutherford 5/6 class ischemia in whom conventional access and the pedal–plantar loop technique have failed. These patients require restoration of flow into the foot to avoid amputation. The transpedal approach requires retrograde percutaneous puncture of a distal patent vessel followed by the retrograde recanalization of the target artery.[32–36]

Retrograde recanalization of the foot arteries can be performed through transmetatarsal (►**Fig. 3**) or transplantar arch retrograde access.[28] This is always performed in combination with antegrade femoral access to allow a rendezvous procedure, angiography, and administration of vasodilators. Transpedal access is technically challenging and in the authors experience approximately 1:6 attempts at transmetatarsal artery access fail due to spasm or failure to reenter the true lumen.

Steps in Performing Percutaneous Retrograde Distal Access

Patient positioning needs to be considered in advance as both femoral and pedal access are required. All of the possible puncture sites need to be prepared and accessible. In our experience, it may be useful for patients to be positioned with their feet at the "head end" of the angiographic table. This maximizes the maneuverability of the image intensifier.

1. *Puncture site selection.* Accurate angiographic evaluation using the correct radiological projection is mandatory for foot arterial puncture. An anteroposterior view obtained with the craniocaudal tilt of the X-ray tube allows correct visualization of the plantar arch and metatarsal arteries.[20]
2. *Vasodilators.* Spasm can compromise the puncture and catheterization of the small vessels, and the use of vasodilators (nitroglycerine and verapamil) is mandatory. These can be administered intra-arterially from an antegrade catheter placed as close as possible to the access site. Vasodilators can also be injected into the subcutaneous tissue together with lidocaine at the arterial puncture site.
3. *Puncture technique.* The best approach is from the dorsum of the foot; plantar access is not practical because of skin thickness. Arterial puncture is performed with a 21 G, 4 cm long needle, under fluoroscopic guidance at maximum magnification. Angiography from the antegrade catheter may help identify the target artery, as does calcification in the artery wall. Ultrasound guidance is sometimes possible using a high frequency probe; the authors use an 18 MHz hockey stick probe with a small foot print.
4. *Passage of the guidewire.* The dorsal branch of the first metatarsal artery usually provides access to the plantar arch and from this it is possible to recanalize the DPA or the LPA and thence the PTA (►**Fig. 3**). When the first metatarsal artery is occluded, the plantar arch can be punctured directly (►**Fig. 4**).
5. *Retrograde crossing strategy.* The authors generally use a 0.018 guide wire after the puncture, because of the enhanced support. A coronary guidewire such as the V18 (Boston Scientific; Marlborough, MA) is one option due to its combination of a short soft hydrophilic tip and a highly supportive shaft.
6. *Catheters and sheaths.* After guidewire access is achieved, a catheter or sheath is required. The authors prefer to use a sheathless approach but if necessary will use a 3-French microsheath (Cook Medical, Inc.; Bloomington, IN) that allows changing guide wires and support catheters. A low profile support catheter as CXI 18 (Cook) is very useful for wire support, orientation, and exchange.
7. *Rendezvous.* The guidewire is manipulated in retrograde fashion through the occluded vessel to reach the proximal patent arterial segment, with the aim of performing a rendezvous with the antegrade catheter.[14,37] If the guidewire cannot be manipulated into the angiographic catheter, it should be captured with a microsnare. Once rendezvous is achieved, the retrograde wire is externalized at the groin level.

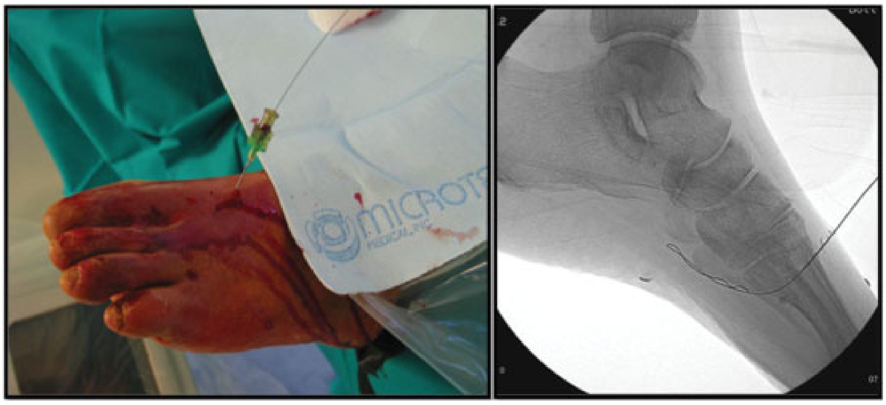

Figure 4 Clinical and fluoroscopic image from a pedal plantar loop technique puncture.

8. *Angioplasty.* A low profile dedicated 0.014, 1.5 mm × 20 mm single marker over-the-wire balloon (Armada XT, Abbott Vascular, Santa Clara, CA; Coyote ES, Boston Scientific) is the first choice in severely calcified long occlusions. Through an over-the-wire balloon, it is always possible to inject vasodilatory drugs (nitrate 0.5 mg/1 mL, Ca-blockers 5 mg/2 mL) to prevent spasms as well as injecting contrast medium when necessary. Moreover, it is possible to change wires according to navigation or support needs. The authors use the shortest and thinnest balloons to maximize the possibilities of crossing success and to predilate all the lesions before the definitive dilatation, performed with a long dedicated balloon at nominal pressure for at least 2 minutes. The authors prefer 20/22 cm long balloons: diameters range from 2.5 to 3.0 mm from the origin of tibial vessels to ankle level in the majority of patients. Foot arteries can be dilated from 1.5 to 2.0 mm at the arch level to 2.0 to 2.5 mm at pedal or plantar arteries level. Repeated and prolonged inflations are indicated when residual stenosis, dissections or fissurations occur. Oversizing should be avoided whenever possible, and progressive step by step upsizing is preferable. The authors also consider compliant high pressure balloons (Pacific Plus 0.018, Amphirion Plus 0.014; Medtronic, Minneapolis, MN) for focal calcified residual stenoses or in treating lesions with significant recoil. Again, a step-by-step pressure increase together with a fluoroscopic check is mandatory. Whenever severe pain occurs at the beginning of balloon inflation, especially at very low pressure (less than four atmospheres), the authors suggest to deflate the balloon and inject Lidocaine 2% (up to 100 mg) into the vessel, to avoid prolonged spasms, acute thrombosis, and potential fissurations. In the author's experience, no systemic effects as arrhythmia have occurred using this algorithm. This protocol may be especially useful when treating young patients, females especially, Buerger disease, and all the inflammatory arteritis (LES, Scleroderma, and Takayasu).
9. *Hemostasis.* After angioplasty, hemostasis at the pedal puncture site is obtained by balloon occlusion. A balloon is either advanced across the puncture site or, if this is not possible, inflated in the plantar arch across the origin of the metatarsal artery. The balloon is kept inflated at low pressure (not exceeding the lower nominal pressure) for at least 4 minutes after microsheath removal.

These extreme distal retrograde techniques can also be used as rescue procedures when a retrograde pedal or common plantar arteries access leads to dissection and acute occlusion.

Radiation Protection

The interventional radiologist has to be aware of radiation exposure[38] associated with transpedal access due to the use of high magnification and high dose screening combined with working in proximity to the target vessels. The authors compared fluoroscopy time and radiation dose in patients treated by mean of antegrade revascularization and patients treated by transmetatarsal artery access. The results show a significant increase in fluoroscopy time and radiation dose (94.0 ± 26.5 Gym2 vs. 69.1 ± 83.2) in the group treated by transmetatarsal artery access. Operators should, as always, keep screening to a minimum and use X-ray protection devices such as protective gloves and glasses. In addition, using a needle extension device such as the Spectranetics

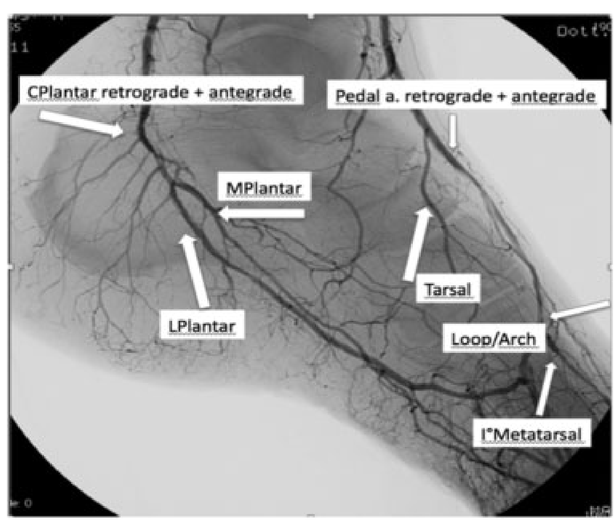

Figure 5 Lateral foot angiographic image demonstrating multiple possible arterial puncture sites.

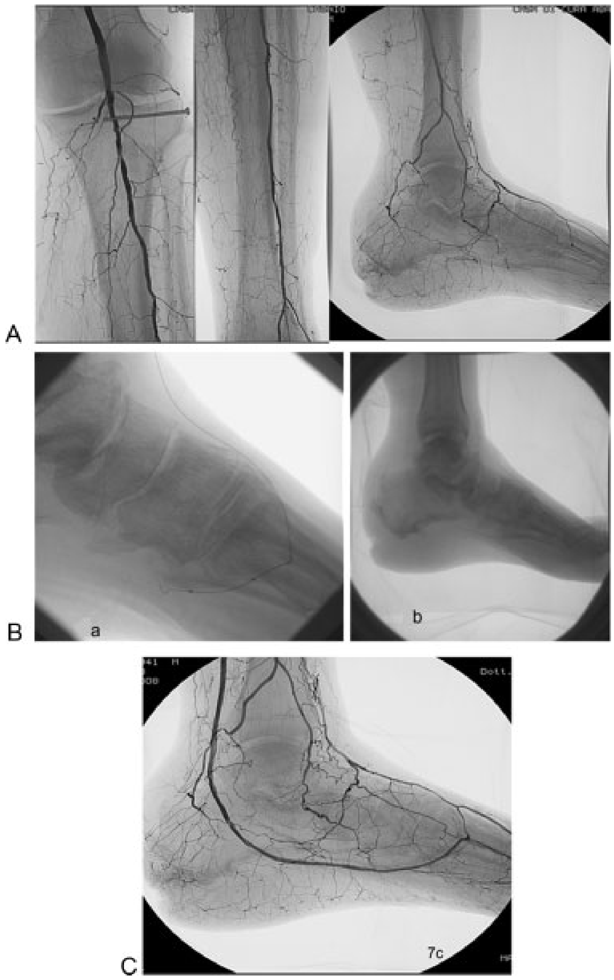

Figure 6 Antegrade pedal artery puncture. (A) Preangioplasty angiography demonstrating multiple occlusions in multiple vascular distributions. (B) Spot images during antegrade pedal artery technique; (a) occlusion of anterior and posterior tibials without any stumps; wound in calcaner region need posterior tibial artery recanalization; (b) antegrade puncture of pedial artery and trans-arch recanalization of lateral plantar and posterior tibial. (C) Postangioplasty angiography demonstrating excellent angiographic response; final result showing direct posterior flow with blushing in the calcanear wound.

(Colorado Springs, CO) quick access needle holder helps to increase the working distance away from the primary beam.

There are modified distal puncture (►**Fig. 5**) techniques such as antegrade puncture of a pedal artery or the common plantar artery. These approaches further enhance the utility of the technique. Fluoroscopic and ultrasound-guided puncture techniques, as well as pharmacological preparation of the puncture site, are the same as described earlier.

As an example, consider the patient with a calcaneal ulcer in whom the ATA and PTA are occluded flush with their origins. Restoring flow in the PTA can be achieved via antegrade puncture of the DPA and a transarch retrograde catheterization of the LPA; retrograde recanalization of the PTA can then be achieved (►**Fig. 6**).

Conclusion

Endovascular treatment is increasingly becoming the first choice strategy for patients with CLI. Antegrade access remains the first choice for BTK intervention. The pedal plantar loop is an adjunctive technique that can help achieve target artery perfusion from the antegrade approach. Transpedal access should be considered where antegrade access has failed, and increases the scope of revascularization procedures particularly in diabetic patients where there is extensive disease BTK. Operators need to be familiar with techniques and equipment required when using these unconventional approaches.

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